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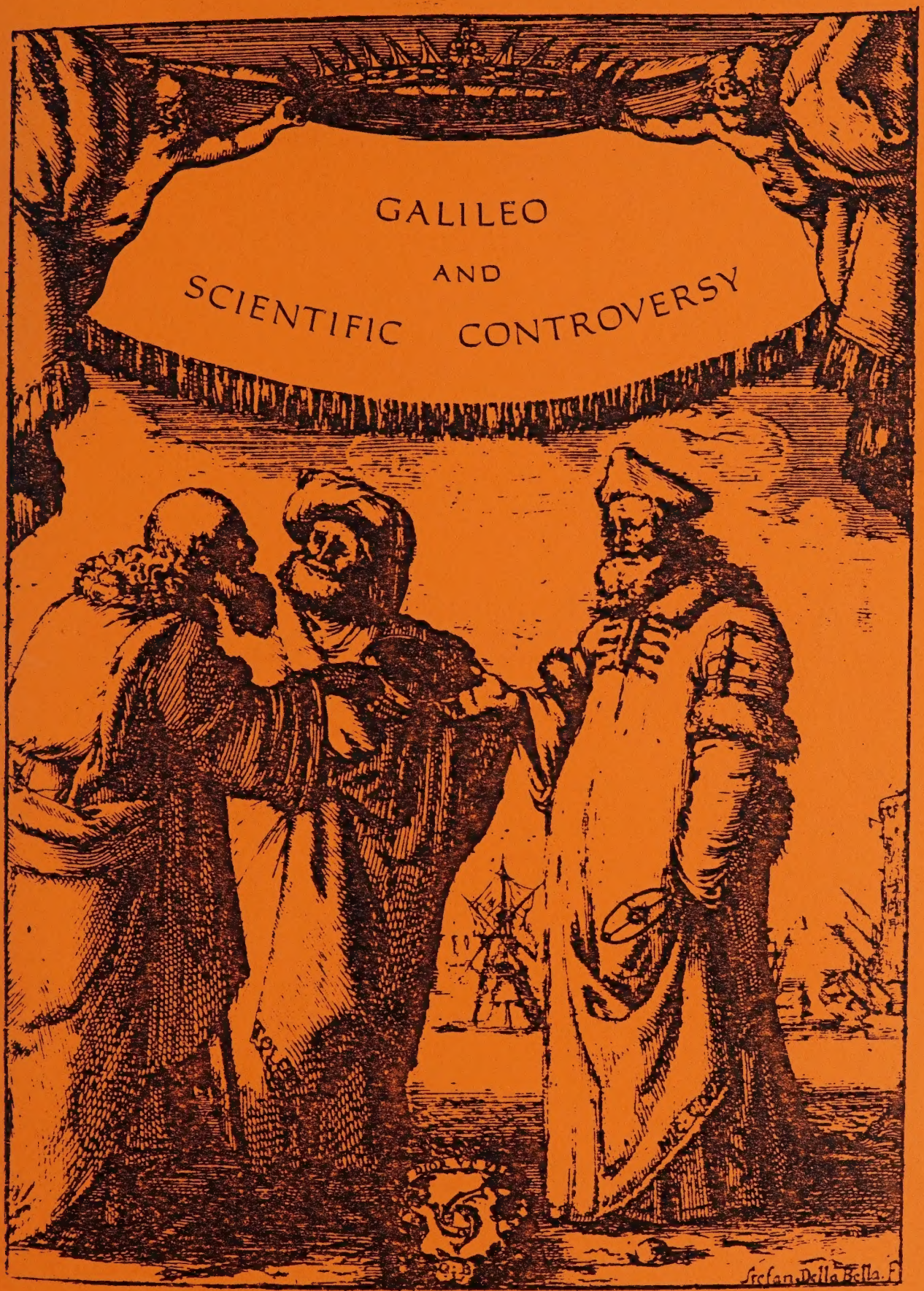

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GALILEO AND SCIENTIFIC CONTROVERSY

An Exhibition at the
Thomas Fisher Rare Book Library
University of Toronto

November-December 1981

On the occasion of
the Sixteenth Annual Conference on Editorial Problems
November 6-7, 1981

This exhibition has been mounted on the occasion of the sixteenth annual Conference on Editorial Problems, to be held at the University of Toronto on November 6th and 7th. The theme of this conference is the editing of scientific texts and the programme of distinguished speakers includes Stillman Drake, Linda Voigts, Bert S. Hall, Armand Beaulieu, and I. Bernard Cohen. It thus seems appropriate to display something of the rich holdings of Galileo and his associates which are part of the extensive collections in the history of science in the Thomas Fisher Rare Book Library. The presence of Professor Stillman Drake on the programme has given this exhibition a particular focus, for most of the books and manuscripts displayed have been part of his internationally renowned Galileo collection, and, indeed, some of them still are. The Thomas Fisher Rare Book Library has had the opportunity of acquiring significant parts of this remarkable collection and now possesses a Galileo Collection which is one of the strongest concentrations of its kind in the world.

Any public exhibition must attempt to appeal to a wider audience than that provided by a single, specialized conference. Indeed, it might be assumed that the delegates to this Conference on Editorial Problems are the least in need of a guide to such an exhibition. Many people, however, will view these books and manuscripts: students, faculty from other disciplines, and interested members of the general public. Thus this catalogue attempts to provide brief explanatory notes on each item and its context in the exhibition so that the full range of Galileo's scientific achievements may be appreciated.

Galileo's scientific career may be viewed as a series of controversies, beginning with his earliest published work on the "new star" of 1604 and

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extending long after the publication of his last major work in 1638. Each of his publications provoked attacks by the philosophers and, occasionally, defences by his scientific colleagues. He replied to his opponents, including the ecclesiastical establishment, with vigour and humour and persisted in the belief that accurate observation and the vigorous application of the new scientific methods would ultimately prevail.

The precise nature of Galileo's scientific achievement, the predominent influences that formed his "philosophy of science", and the extent of his own influence, both scientific and cultural, are still matters for debate. It will be obvious that the purpose of this catalogue is principally descriptive. It will also be obvious that the author's greatest debt is to the scholarly research of Stillman Drake, who has not only brought together the primary sources which make up the exhibition but has also provided the historical perspective.

Richard Landon
October 1981

EAST READING ROOM - THE SOURCES OF CONTROVERSY

Aristotle. Mechanica. Venice, 1497

The Aristotelian canon, constituting a profound and pervasive system of universal knowledge based on a philosophy of substantial things, held its authority through the Medieval period and the Renaissance right into the age of scientific revolution. Although there were many editions, with commentaries, published during the early period of the printing press it was not until 1495 that Aldus Manutius in Venice began to issue his great edition of the texts in Greek. The Mechanics, now classed as "pseudo - Aristotelian" was used by Galileo in the composition of lectures he delivered at the University of Padua and elsewhere during the 1590's. However, Galileo early challenged Aristotelian authority on several specific fronts and remarked, in his On Motion, that "truth has the property that it is not so deeply concealed as many have thought: indeed, its traces shine brightly in various places and there are many paths by which it is approached." The philosophers, often Galileo's opponents, preferred their "truths" to be enshrined in the works of "the master of those who know" and thus, in a sense, most of the many controversies with which Galileo was involved over a long career resulted from the basic conflict between authority and experimental observation.

Johannes Müller (called Regiomontanus). Epytoma in Almagestum Ptolemaei. Venice, 1496.

The Almagest of Ptolemy, a great encyclopaedia of ancient astronomical knowledge, provided, together with the Cosmographia, an authoritative structure for the entire physical universe. Because the Ptolemaic conception of the universe was dominant from the second to the sixteenth century his influence on the philosophers of Galileo's time was almost as significant as that of Aristotle. This edition, with the commentary of Regiomontanus, provides the first published Latin text, translated from the Greek. Regiomontanus (actually Müller's birthplace) continued a translation of an abridged version of the Almagest begun by his teacher Peuerbach in Vienna. No complete translation by Regiomontanus was ever published, but he did complete this Epitome, a scholarly summary of commentaries. This edition was used by Copernicus for his work on a new heliocentric system. The woodcut illustrates the Ptolemaic universe, complete with astrological signs, and underneath it sit Ptolemy and his interpreter, Regiomontanus.

Euclid. Elementa Geometriae. Venice, 1543.

Euclid's Elements of Geometry, the oldest extant mathematical textbook, was a compilation of all ancient Greek knowledge of the subject, conven-

iently arranged in a logical system of theorems and demonstrations. Galileo first began his studies of Euclid in 1583, after hearing lectures by Ostilio Ricci. It seems probable that he used Niccolo Tartaglia's Italian translation of 1543, the first vernacular Euclid, because it clarified the confusion created by the Eudoxian theory of proportion contained in Book Five of earlier Latin editions of Euclid. This theory was crucial to Galileo's important work on acceleration and falling bodies. Tartaglia, a brilliant self-taught mathematician and pioneer of the science of artillery, is best remembered for his Nova Scientia (1537), a treatise on ballistics, surveying and fortification. The mechanical principles of the flight of projectiles were finally elucidated by Galileo in the Two New Sciences of 1638.

Politi, Bassano. Questio de Modalibus ... Venice, 1505.

The influence of medieval treatises on proportion by such scholastics as Thomas Bradwardine, Nicholas Oresme, and Blasius of Parma on the work of Galileo has been the subject of some debate among modern scholars. Galileo's theorems on accelerated motion, given their final form in the Two New Sciences, took into account the earlier theories. This collection of works begins with a treatise on proportion by Bassano Politi, who edited the medieval works on that subject and made them available to Renaissance scholars.

Nicolaus Copernicus. De Revolutionibus Coelestium. Basel, 1566.

Copernicus' great work, which effectively altered the human perception of the universe, was first published in the year of his death, 1543. The system, with the sun at the centre and the earth in motion, did not become controversial until its principles began to be advocated by the leading scientists, such as Galileo and Kepler. Galileo seems to have first become seriously interested in Copernican astronomy in 1595, in relation to a theory of the tides. It wasn't until he had the opportunity of observing the phases of Venus through a telescope in 1610 that he could finally confirm the correctness of the Copernican view; the theological questions raised by his advocacy of the system came later. This copy of the second edition of De Revolutionibus belonged to Philip van Lansberge, a German mathematician, and a Protestant, who advocated the Copernican system in his Progymnasmatum Astronomiae (1619) and other works. He has extensively annotated this copy and has written an outline for a proposed work (De Motibus qui circa Terram) on the blank leaves at the end.

Guidobaldo del Monte. Mechanicorum Liber. Pisa, 1577.

The first modern treatise on mechanics was published by Guidobaldo, a talented amateur scientist, in 1577. In 1588 Galileo sent to him some theorems on centres of gravity of parabolic solids, at the same time as Guidobaldo's commentary on the work of Archimedes appeared. They became

friends and Galileo's Mechanics was possibly influenced by Guidobaldo's work. They had also both worked on the Archimedian screw, a device for raising water: Galileo obtained a patent for a water-raising device in 1594, but Guidobaldo's treatise De Cochlea did not appear until 1615, eight years after his death.

Giovanni Battista Benedetti. Diversarum Speculationum. Taurino, 1585.

Benedetti, the leading Italian physicist of his time, studied mathematics under Tartaglia and eventually held the position of court mathematician to the Dukes of Parma and Savoy. He published an argument for equal speed of fall by bodies differing in weight but of the same material in 1553, defended and amplified it in 1554, and refined the theory in this work of 1585. It is possible that Galileo had seen Benedetti's work before composing his unfinished "Dialogue on Motion" in 1586-87, but he did not adopt Benedetti's explanation of acceleration in fall.

Ostilio Ricci. L'uso dell Archimetro. Manuscript, ca. 1600.

Ricci was born in 1540 and is said to have studied mathematics under Tartaglia. By 1583 he had become attached to the Tuscan court where Galileo heard his lectures on Euclid. Later he held the position of supervisor of fortifications at Florence (succeeding Guidobaldo) and became a hydraulic engineer. When he died in 1603 he held the title of mathematician to the Grand Duke, a position Galileo was later to occupy. Ricci taught in Italian and thus probably used Tartaglia's translation of Euclid. He composed various works, one of which was a treatise on a surveying instrument called an "archimetro", which he may also have invented. None of his works was ever printed and published, and this manuscript, a contemporary scribal copy illustrated with exquisite drawings, is one of the few accounts of his work to survive. This manuscript also contains an account of Galileo's proportional compass.

CASE I - THE EARLY WORK AND THE NEW STAR

Galileo Galilei. Cosmografia. Manuscript, ca. 1600

Galileo's "Treatise on the Sphere, or Cosmography", which survives in only five manuscript copies, was probably composed during 1586-87 for his private teaching, as it is written in Italian. The body of the work discusses climatic geography and spherical astronomy and follows the thirteenth-century Sphere of Sacrobosco. The short introductory preface to this work is, however, considered to have been composed around 1602, for Galileo expanded his private tutoring at this time. The preface describes the method of the cosmographer, largely taken from the introduction to Ptolemy's Almagest, but remarks that in cosmography "as in

other sciences, the subject should be pointed out, and then we should touch on the order and method to be followed ..." It has been suggested that Galileo viewed the method of the cosmographer as also applicable to physics; that is, a "scientific" rather than a "philosophical" approach as taught by Peripatetics in the universities.

Galileo Galilei. Mechaniche. Manuscript, ca. 1650.

------- -------. Della Scienze Mecanica. Ravenna, 1649.

Galileo composed in 1593 a brief treatise on mechanics, as a syllabus for private instruction, expanded it in 1594 and greatly extended it in 1601-2. He was possibly initially influenced by Guidobaldo's work of 1577 but by 1602 his special interest in mechanical problems had altered the approach and emphasis of the whole work. He was not, as he had been in 1594, concerned with causes but rather with practical definitions and postulates from which could be derived and demonstrated laws of physics. Although many manuscript copies of the "final version" of the work survive it was not published until Mersenne translated it into French and issued it in 1634. The first Italian edition (the language originally used) did not appear until 1649, edited by Luca Danesi. This manuscript and the 1649 edition both show the same simple diagrams although the image of the balance beam is reversed.

[Galileo Galilei] Dialogo de Cecco di Ronchitti ... de la Stella Nuova. Padua, 1605.

On October 9th, 1604 a new star was first observed in the heavens near the conjunction of Jupiter and Mars in Sagittarius. Because of its brightness and the many astrological inferences that could be drawn from its appearance, considerable interest in this event was evinced by a number of Aristotelian philosophers. Galileo, for the first time, became seriously concerned with astronomical matters and the nova of 1604 became the centre of his first great controversy. He gave three public lectures in the autumn of 1604, which have not survived, but during the course of which he discussed the parallax and measurement of distance and attempted to refute the Aristotelian theory that novae were sublunar phenomena. He was challenged by Cesare Cremonini, among others, and replied in this pamphlet under a pseudonym. The Dialogue, written in rustic dialect with two peasants as spokesmen, scornfully dismissed philosophical astronomy and insisted on measurement as the only method of determining the exact nature of heavenly bodies.

Baldessar Capra. Consideratione Astronomica circa la Nova ... Padua, 1605.

These first observations of the New Star at Padua were begun on the night of October 10th, 1604 by Capra and his mathematical tutor, Simon Mayr.

Capra's remarks were published early in 1605 but were not replied to directly by Galileo except, possibly, in a letter to Guidobaldo del Monte of Feb. 1606. Capra was to prove himself a more troublesome opponent the following year.

Antonio Lorenzini. Discorso ... intorno alla Nuova Stella. Padua, 1605.

Lorenzini, an amateur astronomer and philosopher, published this pamphlet as an attack on Galileo's lectures on the nova of 1604. It is likely, however, that much of it was in fact written by Cesare Cremonini, a personal friend but scientific opponent of Galileo. The Discorso presents the Aristotelian views of "philosophical induction" where objects located at a great distance cannot be made dependent on measurement. The Dialogue of "Cecco di Ronchitti" was Galileo's direct reply.

Lodovico delle Colombe. Discorso ... nel quale Si demonstra che la Nuova Stella apparita ... Florence, 1606.

Colombe, a philosopher, amateur astronomer, and poet from Florence, entered the controversy concerning the new star early in 1606, after it had disappeared from view. His Discorso put forward the opinion that the star was not "new" at all and promised to reconcile this theory with all true astronomy, philosophy and theology. The answer to this attack was published in Florence in June 1606 by "Alimberto Mauri" and called Considerazioni ... sopra Alcuni Luoghi de Discorso di Lodovico delle Colombe (a copy of this work is in the collection but not displayed) "Mauri" suggested, sarcastically, that Colombe had better stick to philosophical astronomy and leave mathematics to those qualified to make accurate observations. Colombe could never discover the real identity of "Alimberto Mauri" and came to believe that Galileo had written the pamphlet himself. He was probably right.

CASE II - THE PROPORTIONAL COMPASS

Galileo Galilei. La Operazione del Compasso Geometrico. Padua, 1640.

------- -------. De Proportionum Instrumento ... Strassburg, 1613.

Some time around 1598 Galileo invented and perfected a military compass which could solve easily and quickly most practical mathematical problems of the time. He drew up a manual of instructions for its use and employed an artisan to manufacture the instruments for sale. He did not, however, immediately publish the manual, from fear of plagiarism, and when it was finally published in 1606 in Padua the edition was limited to sixty copies and no illustration of the compass was included. The complete

work, in Italian with an engraved illustration, did not appear until 1640. In 1613, however, Mathias Bernegger, an Austrian historian, translated the Compass into Latin and published it, with some additions of his own.

Baldessar Capra. Usus et Fabrica Circini cuiusdam Proportionis ... Bologna, 1655. [Second edition]

Despite Galileo's precautions his work on the compass was plagiarized in 1606 by Baldessar Capra, who added insult to injury by claiming priority of invention. As Galileo had dedicated his work to Prince Cosimo de' Medici he was placed in the embarrassing position of having seemed to dedicate a work to the Prince which was not his own and he reacted strongly. He secured affidavits from several persons who had been supplied with instruments years before and brought charges against Capra. The University officials investigated the case, found Capra guilty of plagiarism, expelled him from the University and confiscated unsold copies of his book (which perhaps accounts for its rarity)

Galileo Galilei. Difesa ... contro alle Calunnie & Imposture di Baldessar Capra. Venice, 1607.

Galileo was not entirely satisfied with the clearing of his reputation at the trial. Some copies of Capra's book had been sold outside Venice and thus he wrote a formal Defence, including an account of the University proceedings, to be sent to Cosimo de' Medici and foreign mathematicians. This further established his claim to the instrument which long continued to be manufactured.

CASE III - THE TELESCOPE DISCOVERIES

Galileo Galilei. Sidereus Nuncius. Frankfurt, 1610.

Galileo's "Starry Messenger" was written early in 1610 and was first published in March in Venice. The second edition appeared later the same year in Frankfurt. It resulted from a series of telescopic observations, beginning in 1609, and carried out by Galileo using instruments he had constructed himself. The telescope seems to have been invented in Holland in 1608 and news of it, in the form of a "news letter," quickly spread throughout Europe. Galileo constructed several instruments, each of increasing power, and on Jan. 7th, 1610 discovered some moons of Jupiter, or the Medicean Stars, as he called them. This discovery and his observations on the roughness of the surface of the moon, which was illustrated with woodcuts, were published in the Sidereus Nuncius.

Johann Kepler. Dissertatio cum Nuncio Sidereo. Florence, 1610.

A copy of Galileo's Sidereus Nuncius had been sent to Kepler shortly after it was published and he was asked officially to comment on it. On April 19th, 1610, Kepler sent to Galileo a long commentary which substantially supported his conclusions, although Kepler had not been able to make accurate observations himself for want of a suitable telescope. Galileo and Kepler had corresponded as early as 1597 concerning Copernicus and Kepler's support was to prove useful in later controversies. Kepler's most important work, Astronomia Nova, which promulgated his first and second laws of planetary motion, had been published in Prague in 1609 and he was to issue a whole series of important works culminating in his great revision of the Rudolphine Tables, published in 1627 and based on the observations of Tycho Brahe, his teacher.

Francesco Sizzi. Dianoia Astronomica. Venice, 1611.

The reactions to Galileo's Sidereus Nuncius began to appear almost immediately. Sizzi, a young Florentine patrician, obtained a license to publish his Dianoia in August 1610 although it did not appear until 1611. He did not believe in the existence of any new "planets" and introduced, for the first time, theological arguments to prove his case.

Giulio Cesare Lagalla. De Phoenomenis in Orbe Lunae ... Venice, 1612.

Lagalla, a professor of logic in Rome, opposed Galileo's anti-Aristotelian conclusions regarding the roughness of the moon's surface, which he declared to be a smooth and perfect sphere. The support of his views by the scholastics and logicians illustrates the typical reaction of many to observation and the use of scientific method.

CASE IV - BODIES IN WATER AND SUNSPOTS

Galileo Galilei. Discorso ... intorno alle cose, che Stanno in sù l'Acqua. Florence, 1612.

Galileo's Discourse on Bodies on or in Water, his first work dealing with experimental physics, was completed in the Spring of 1612. In it he mentioned the satellites of Jupiter and sunspots but concentrated on a dispute which had arisen during August 1611 between Galileo and a group of philosophers (including Vincenzio di Grazia and Colombe) over the reasons why ice floats in water. For this work Galileo had to define what is now known as "specific gravity". Although not as

generally popular as the Sidereus Nuncius it attracted attention and the further opposition of the philosophers.

[Papazzoni, Flaminio] Considerazioni sopra il Discorso del Sig. Galileo Galilei. Pisa, 1612.

The first published reply to Galileo's Bodies in Water was made by Papazzoni, who held the chair of philosophy at the University of Pisa, a position he gained with the recommendation of Galileo. It was the most reasonable and dignified of all the works written against this book, merely putting forward the Aristotelian position. The Considerations was, for a long time, attributed to Tommaso Palmerini and, more recently, to Arturo D'Elci. The evidence for Papazzoni's authorship is presented by Prof. Drake in the preface to his Galileo's Discourse on Bodies (1960).

Lodovico delle Colombe. Discorso Apologetico d'intorno al Discorso di Galileo. Florence, 1612.

Colombe, who had earlier entered into the dispute over the new star of 1604, led the opposition to Galileo's works at Florence from 1610 to 1614. This is the third work written against Bodies in Water (the second, by Giorgio Coresio, is in the collection but not displayed) and was designed to cast doubts on Galileo's experiments.

Vincenzio Di Grazia. Considerazioni ... sopra'l Discorso di Galileo Galilei. Florence, 1613.

In June 1613 the fourth attack on Bodies in Water appeared. It was written by Vincenzio Di Grazia, one of the participants in the verbal dispute of 1611, and repeated the standard Aristotelian arguments. Galileo drafted replies to all four works but turned them over to Benedetto Castelli, one of his students and closest associates. They eventually were published in 1615.

[Christopher Scheiner] Tres Epistolae de Maculis Solaribus. Augsburg, 1612.

Scheiner, a Jesuit who taught mathematics at Ingolstadt from 1610 to 1616, became one of Galileo's bitterest opponents. On January 6th, 1612, Mark Welser, a banker and man of affairs from Augsburg who had become interested in scholarly controversies, sent to Galileo a small booklet on sunspots written by someone calling himself "Apelles", later identified as Scheiner. Apelles argued that the spots were really moving stars or planets revolving about the sun. Galileo, who had previously observed sunspots, then devoted most of 1612 to making a

series of careful observations and replied to Apelles in a series of three letters, addressed to Welser.

Galileo Galilei. Istoria e Dimostrazioni intorno alle Macchie Solari. Rome, 1613.

Galileo's three letters on sunspots, addressed to Welser, were submitted for publication to Federico Cesi, an aristocratic patron of science who had founded the Lincean Academy for scientific studies in 1603. All three appeared together in this book with the official imprimatur of the Academy and were published in Rome. Two "issues" were required: seven hundred copies were printed with Scheiner's three Letters added as an appendix for the benefit of the Italian market and seven hundred were issued without the appendix for international sale, Scheiner's work being protected by copyright outside Italy. Galileo argued in this work that the sunspots were "contiguous to the surface of the solar body, where they are continually generated and dissolved". The especial importance of this work is that it contains Galileo's first unequivocal endorsement of the Copernican system to be published. It also included a remarkable series of engraved diagrams that correctly predicted the positions of the satellites of Jupiter (the Medicean Stars) for the months of March and April (the Sunspot Letters was published on March 22nd, 1613). Galileo was thus able to demonstrate the correctness and accuracy of his methods of observation.

Benedetto Castelli. Risposta alle Opposizioni del S. Lodovico delle Colombe ... Florence, 1615.

In 1615 Castelli's reply to the attacks on Galileo's Bodies in Water was published. It was compiled from notes made by Galileo during 1612 and 1613 as the four pamphlets by Papazzoni, Coresio, Colombe and Di Grazia appeared. Only the works of Colombo and di Grazia were answered directly, as Papazzoni had died and Corezio had fallen into disgrace by 1615.

CASE V - THE LETTER TO CHRISTINA

[Paolo Antonio Foscarini] Lettera ... sopra l'Opinione ... del Copernico. Naples, 1615]

Foscarini, a Carmelite Father from Naples, entered the controversy concerning the use of scriptural authority in scientific matters with this work and went to Rome to debate with the philosophers in favour of Copernicus in 1615. Galileo was encouraged by Foscarini's book to oppose church action against the system of Copernicus and wrote his Letter to the

Grand Duchess Christina as a result. Thomas Salusbury translated Foscarini's Letter into English and published it with Galileo's works in 1661.

Galileo Galilei. Alla Serenisma Madam La Granduchessa. Manuscript, early 17th century.

------- -------. Nov-Antiqua Sanctissimorum Patrum & Probatorum Theologorum Doctrina De Sacrae Scripturae Testimoniis. Strassburg, 1636.

------- -------. Galileo a Madama Cristina. Padua, 1898.

Galileo wrote his Letter to Christina, as it is generally called, to reconcile free discussion of the Copernican system with the writings of the Church Fathers. He did not, however, publish it and it did not appear in print until 1636, and then without his permission. This manuscript copy is one of several put into circulation in Italy during the early seventeenth century and differs somewhat from the published text. Galileo had revised and expanded an earlier "letter" to Castelli in this work, which was to become of crucial importance to his career. Christina was the Grand Duchess of Tuscany and mother of Cosimo II de' Medici. She actively supported Galileo's work. The Letter to Christina again appeared in 1896 as the "littlest giant", the smallest book printed with moveable type.

CASE VI - THE CONTROVERSY OF THE COMETS

[Orazio Grassi] De Tribus Cometis. Rome, 1619.

In the Autumn of 1618 three comets were sighted and aroused great interest in Rome. Grassi, a Jesuit professor of mathematics at the Collegio Romano, lectured publicly on the comets and, in particular, discussed their distance from the earth which he believed to place them among the planets. His anonymous publication on the subject began the "controversy on the comets" which was to culminate in Galileo's Saggiatore in 1623.

Mario Guiducci. Discorso delle Comete. Florence, 1619.

Galileo was asked to comment on the comets but was, by this time, prohibited from writing on astronomy. He thus chose to reply to Grassi under the name of Guiducci, his assistant and the newly elected Consul of the Florentine Academy. Most of the surviving manuscript of the Discourse on Comets is actually in Galileo's hand. In it he ridiculed Grassi's astronomical theories, reviewed ancient

notions concerning comets and Tycho Brahe's views based on his observations of the comet of 1577, and set forth his own observations.

[Orazio Grassi] (Lotorio Sarsi, pseud.) Libra Astronomica ac Philosophica ... Perugia, 1619.

Grassi replied to the Discourse, incorporating the comments of Scheiner, who had been offended by a comment about "Apelles", with the Astronomical Balance, which pretended to weigh the opinions of Galileo, as set forth by Guiducci. It contained several personal attacks against Galileo and was scientifically inept. Galileo decided, for the moment at least, not to publish a further reply.

Mario Guiducci. Lettera al M.R.P. Tarquinio Galluzzi. Florence, 1620.

Guiducci, however, decided to protest the treatment he had received in the Libra Astronomica by publishing a letter he addressed to his former professor of rhetoric, Galluzzi. It described some experiments designed to counter those used in the Libra, but was moderate in tone.

Galileo Galilei. Il Saggiatore. Rome, 1623.

Galileo's final reply to Grassi, addressed as a letter to Virginio Cesarini, a fellow member of the Lincean Academy from Rome, was one of the greatest polemics in the history of scientific controversy. While dealing with the astronomical issues raised by the controversy on the comets, especially the methods used by Grassi, The Assayer opened up a whole series of questions concerning scientific investigation. The common English translation of the title, The Assayer, conveys the sense of a fine balance, used to weigh gold, as opposed to Grassi's crude "balance". It remained Galileo's most complete statement of his philosophy of science. The manuscript was sent to Cesi in Rome early in 1623 as it was to be published by the Lincean Academy, and it was approved for publication by the Holy Office. There were some delays in printing and when Maffeo Barbarini became Pope Urban VIII in August the Academy decided that he should receive the dedication. Accordingly the title page was altered to include the Barbarini coat of arms. The first issue, published in late October, contained a handsome portrait of Galileo and two poems in praise of him by Johannes Faber and Francesco Stelluti. A later issue lacks both. The first issue also contained numerous errors due to the incompetence of the editor, a man called Stigliani, with only a few errata. When Galileo had an opportunity to go through the published text he ordered almost three pages of errata to be printed, one example of which survives separately. The second issue had its final leaf cancelled and one full page of errata inserted. A copy of the first issue, with the errata inserted, is displayed open at page 113, where Galileo has himself written a manuscript correction at a passage Stigliani has inserted in praise of himself.

Orazio Grassi. Ratio Ponderum Librae et Simbellae. Paris, 1626.

Grassi's final work on the comet controversy and a reply to The Assayer was first published in Paris in 1626 and reissued in Naples the following year. Again he used the pseudonym "Lothario Sarsi" and again he failed to make much of an impression on Galileo's principal arguments.

CASE VII - THE DIALOGUE

Christopher Scheiner. Rosa Ursina. Bracciano, 1626-30.

Scheiner's large book on sunspots remained on the presses from 1626 to 1630. When it finally appeared Galileo and his friends were shocked by its vituperative style and personal unpleasantness. Scheiner asserted his priority for the discovery of sunspots and lavishly illustrated his own observations. It was suggested to Galileo that he should reply in his Dialogue, which he had just completed, and it is possible that a few sentences were inserted to refute Scheiner's claim to priority. The copy displayed once belonged to Sir Christopher Wren.

Galileo Galilei. Dialogo ... Florence, 1632.

Galileo's Dialogue on the Two Chief Systems of the World is his most famous book and its romantic history is well known. The literary form of the dialogue lent itself well to the Aristotelian versus Copernican debate that was carried on over three days by the three interlocutors. The conclusion as to which is the true system is left to the reader but the strongest proofs are presented by Salviati, the Copernican. The Church, in its official capacity, reacted strongly to the Dialogue, placed Galileo on trial and sentenced him to a kind of house arrest for the rest of his life. There have been translations of the Dialogue into many languages. It first appeared in English in 1661, translated by Thomas Salusbury. Its second English translation, published in 1952, was prepared by professor Drake and contains a foreword by Albert Einstein.

Antonio Rocco. Esercitationi Filosofiche. Venice, 1633.

Rocco, a Venetian philosopher, published his book against the Dialogue to defend the teachings of Aristotle. Some of Galileo's comments on his work were incorporated into the Two New Sciences, where Rocco's arguments were treated seriously and with respect, though they were misguided by his strict adherence to Aristotelian teaching.

CASE VIII - THE TWO NEW SCIENCES

Galileo Galilei. Discorsi e Dimostrazioni Matematiche. Leiden, 1638.

The Two New Sciences, as it is generally known in English, was Galileo's greatest scientific work. He had begun work on a treatise on motion thirty years previously and took it up again after he had finished writing the Dialogue. It was completed at his villa while he was under arrest and the manuscript was sent to Louis Elzevir the famous publisher in Leiden for publication. The Two New Sciences provided a basis for the work of Huygens and Newton in the science of motion.

Marin Mersenne. Les Nouvelles Pensees de Galilee. Paris, 1639.

Mersenne, best known for his work on the theory and practice of music, corresponded extensively with all the principal scientists of his time and published both their works and his own. In 1639 he presented, in French, the important scientific discoveries from the Two New Sciences, and thus made them readily accessible to the scholars of Europe.

Honoré Fabri. Tractatus Physicus de Motu Locali. Lyon, 1646.

Galileo died in 1642, but the controversies he had raised did not. His theories were ably defended by his students and later scientists, but his ideas continued to be questioned. Fabri, a French scientist, published his Tractatus to interpret Galileo's experimental results from the Two New Sciences in terms of medieval impetus theory.

Giovanni Battista Baliani. De Motu Naturali ... Geneva, 1646.

Baliani's book on motions of solids had been composed during the 1620's but was not published until 1638. This second edition proposed the further topic of motions of fluids and introduced an impetus - theory explanation of acceleration in fall similar to Fabri's. Baliani had corresponded with Galileo since 1614.

Jacques-Alexandre Le Tenneur. De Motu Naturaliter Accelerato. Paris, 1649.

Le Tenneur, a friend of Mersenne and correspondent of Gassendi, was the only mathematical physicist of his time to appreciate correctly the significance of Galileo's formulation of the proportionality of speeds in free fall to the elapsed times. In his De Motu he was able to reconstruct correctly Galileo's original arguments based on experiments first performed in 1604 and explicated in the Two New Sciences.

Pierre Gassendi. Institutio Astronomica. London, 1653.

Gassendi, a French priest, made a series of astronomical observations, including the first recorded observation of a transit of Mercury (1631). In his Institutio Astronomica he discussed the Ptolemaic, Copernican and Tychonic systems.

WEST READING ROOM - THE TRIUMPH OF GALILEO

Benedetto Castelli. Della Misura dell'Acque Corventi. Manuscript, ca. 1630.

Castelli became a student of Galileo's in 1604 and in 1613 obtained the chair of mathematics at Pisa. He subsequently taught both Cavalieri and Torricelli. Castelli's speciality was hydraulics and he superintended water and drainage projects in Rome. His pioneering work on the measurement of running water was published in Rome in 1628. This contemporary manuscript copy of it was probably made for use by a student.

Evangelista Torricelli. De Sphaera et Solidis Sphaeralibus. Florence, 1644.

Torricelli is best remembered for his invention of the barometer and his work on atmospheric pressure. He also carried on Galileo's work on motion and succeeded him as mathematician to the Grand Duke of Tuscany. His work in pure mathematics was also significant.

Vincenzio Viviani. Quinto Libro degli Elementi d'Euclide. Florence, 1674.

This work contains the first publication of Galileo's last work, a commentary on the fifth book of Euclid's Elements which Galileo had neglected to discuss in the Two New Sciences and had dictated on his death-bed. Viviani was Galileo's last student, living with him at Arcetri from 1639 until his death. In 1647 Viviani succeeded Torricelli as mathematician to the Grand Duke and published many works in mathematics. He also edited the first collected edition of Galileo's Works (1655-56) and collected a mass of manuscript material concerning the life and work of his master, some of which survives in over three hundred volumes in the Biblioteca Nazionale of Florence.

Sir Isaac Newton. The Mathematical Principles of Natural Philosophy. London, 1729.

Galileo's pioneering work in the study of motion and its mathematical analysis was acknowledged by Newton in his Principia, generally called the greatest single work in the history of science. Newton was able to use the accurately described natural phenomena to formulate his universal laws of gravitation and motion, first published in Latin in 1687, but not translated into English until the appearance of Motte's edition. Copies of the first, and all significant subsequent editions, are part of the Fisher Library collections.